

circular cross-sectional inner shape such that the [fine] wire members extend along a straight line along the axial direction of the members.

According to the above description, pressing the inner shaft member into the outer cylindrical member also means pressing the outer cylindrical member around the inner shaft member. Both pressing operations are equivalent and generate the same result.

In the steering devices of the present invention, because a plurality of [fine] wire members is disposed between the inner shaft member and the outer cylindrical member, the dimensional tolerances of the inner shaft member and outer cylindrical member and variations in the surface conditions of the members have little effect on energy absorption performance and thus, a robust technique is achieved.

By experimentation, the inventors confirmed that by interleaving a plurality of [fine] wire members between the inner shaft member and the outer cylindrical member, both of which have circular cross-sections and thus can easily rotate relative to each other, the inner shaft member can be press-fitted within the outer cylindrical member rigidly in the rotating direction and less rigidly along the axial direction so that appropriate energy absorption performance is ensured. A single [fine] wire member disposed between the shaft member and the cylindrical member does not provide the same results as a plurality of [fine] wire members. That is, pressing the circular cross-sectional inner shaft member into the circular cross-sectional outer cylindrical member with a single [fine] wire member interleaved therebetween, while maintaining the appropriate rigidity in the axial direction, decreases rigidity in the rotating direction. Thus, sufficient torque transmission is not provided. In order to overcome this problem, prior art cylinders and shafts have utilized an oval cross-sectional shape, as shown in Japanese Unexamined Patent Publication No. 56-8755 and Japanese Unexamined Utility Model Publication No 56-6669.

Energy absorbing type steering devices according to the present invention provide energy absorption performance that does not vary from device to device. In addition, the inner shaft member and the outer cylindrical member of each steering device are fitted together rigidly in the rotating direction and less rigidly in the axial direction to an appropriate degree. Further, the steering device is manufactured from circular cross-sectional members and [fine] wire members at a relatively low cost.

By applying the present invention to a steering shaft, an inner shaft can be press-fitted within an outer shaft in a manner that reliably ensures transmission of torque from one shaft to the other shaft. Therefore, rotational slippage does not occur. Moreover, by applying the invention to a steering column, the inter tube and outer tube are prevented from rotating relative to each other, which would hinder subsequent assembly steps. If the steering device according to the present invention is utilized between an outer cylindrical member, which is secured to a bracket that is affixed to a vehicle body, and a steering tube, the fitted together steering tube and outer cylindrical member are prevented from rotating relative to each other, which would make it difficult to perform subsequent assembly steps.

In the axial direction of an energy absorbing type steering device, each [fine] wire member is preferably longer than or equal to a length that ensures a clearance between the inner shaft member and the outer cylindrical member when the steering device is absorbing energy, which occurs when the inner shaft member is being pressed more deeply into the outer cylindrical member.

When this requirement is satisfied, uniform energy absorption performance, or energy absorption, is achieved when the inner shaft member axially displaces relative to the outer cylindrical member.

In addition, the difference in Vickers hardness between the inner shaft member and each [fine] wire member or between the outer cylindrical member and each [fine] wire member is preferably at least 200. It does not matter whether the Vickers hardness of [fine] wire member is greater or less than the inner shaft member and the outer cylindrical member.

This requirement ensures plastic deformation of the inner shaft member and outer cylindrical member or plastic deformation of the [fine] wire members when the inner shaft member is press-fitted into the outer cylindrical member. Accordingly, uniform energy absorption performance is ensured regardless of the manufacturing tolerances of the members.

The positions of [fine] wire members are preferably selected in accordance with the pressing load that is required to press-fit the inner shaft member within the outer cylindrical member.

For example, when four [fine] wire members are disposed at regular intervals (i.e., at ninety-degree intervals about the center of the inner shaft member), the inner shaft member is fitted into the outer cylindrical member so as to ensure high axial

rigidity. On the other hand, when two pairs of spaced apart [fine] wire members are disposed such that the angle about the center of the inner shaft member is divided, e.g., into 60 degrees, 120 degrees, 60 degrees, and 120 degrees, the inner shaft member is fitted within the outer shaft member so that low axial rigidity is ensured.

That is, by changing the circumferential arrangement of the [fine] wire members, steering devices having different energy absorption performances can be produced using the same members. Accordingly, energy absorbing type steering devices can be produced by changing the circumferential arrangement of the [fine] wire members in accordance with the pressing load that is required to press-fit the inner shaft member into the outer cylindrical member.

Further, the [fine] wire members preferably are fixedly coupled to an end face of the inner shaft member or the outer cylindrical member in order to prevent movement of the [fine] wire members in the axial direction.

When this requirement is satisfied, the inner shaft member is securely press-fitted within the outer cylindrical member with the [fine] wire members disposed between the members. Also, when energy is applied to the steering device and the inner shaft member becomes more deeply fitted into the outer cylindrical member, the [fine] wire members are maintained at a constant axial position with respect to either the inner shaft member or the outer cylindrical member, thereby ensuring uniform energy absorption performance when energy is absorbed.

A pull-in prevention means is preferably provided at a coupling portion of each [fine] wire member and the coupling portion is attached to the end face of the inner shaft member or the outer cylindrical member. For example, the pull-in prevention means may include a loop in the [fine] wire member that prevents the coupling portion from being pulled into the clearance between the inner shaft member and the outer cylindrical member.

Because the pull-in prevention means prevents the coupling portion from being pulled into the clearance, energy absorption performance becomes substantially uniform.

The present invention also provides innovative methods for assembling energy absorbing type steering devices. Methods for assembling energy absorbing type steering devices, in which an inner shaft member is press-fitted into an outer cylindrical member, are characterized by a step of extending a plurality of [fine] wire members in the axial direction along the outer shape of the inner shaft member or

along the inner shape of the outer cylindrical member and a step of press-fitting the inner shaft member into the outer cylindrical member with the [fine] wire members disposed between the inner shaft member and the outer cylindrical member so that the [fine] wire members provide a clearance between both members.

This method facilitates assembly of steering devices having uniform energy absorption performance.

In the above-described assembling method, at least one of the inner shaft member, the outer cylindrical member, or the [fine] wire members preferably deforms beyond the respective elastic limit thereof. When one deforms past its elastic limit, or is plastically deformed, the adverse effects of dimensional tolerances of the members decrease, which provides an extremely uniform energy absorption performance.

In this method, the load that is applied to press-fit the inner shaft member into the outer tube member preferably is measured and the [fine] wire members are preferably cut when the measured load reaches a predetermined value.

Thus, by using this method, steering devices can be reliably assembled so as to have an energy absorption performance that is adjusted to a predetermined value.

In the alternative, according to this method, a predetermined length of the [fine] wire members may preferably be axially positioned along the inner shape of the outer cylindrical member and the inner shaft member may preferably be press-fitted into the outer cylindrical member while preventing the [fine] wire members from being axially drawn into the outer cylindrical member.

By using this method, the lengths of the [fine] wire members disposed between the shaft member and the cylindrical member can be accurately determined and steering devices that provide uniform energy absorption performance can be more easily assembled.

The present invention further provides innovative apparatus for assembling steering devices. The assembling apparatus includes a device that press-fits an inner shaft member into an outer cylindrical member and a [fine] wire-member supply device that supplies a plurality of [fine] wire members to the clearance between the outer shape of the inner shaft member and the inner shape of the outer cylindrical member. The [fine] wire-member supply device is disposed adjacent to the press-fitting device.

According to this apparatus, steering devices having uniform energy absorption performance are easily and efficiently assembled.

In this apparatus, the [fine] wire-member supply device preferably can be adjusted with respect to the circumferential direction of the inner shaft member and outer cylindrical member. Such an apparatus enables the production of energy absorbing type steering devices having various levels of rigidity with respect to the axial direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 schematically shows a steering tube according to one embodiment of the present invention.

Fig. 2 is a cross-sectional view taken along line II-II shown in Fig. 1.

Figs. 3(A), (B), and (C) show [fine] wire members before and after the steering tube is assembled.

Fig. 4 is a graph showing a relationship between material deformation and load.

Fig 5 shows an assembling apparatus according to a first embodiment.

Fig. 6 is a cross-sectional view of a fitted portion of a steering tube assembled by the apparatus of Fig. 5.

Fig. 7 is a cross-sectional view taken along line VII-VII in Fig. 6.

Fig. 8 shows an assembling apparatus according to a second embodiment.

Fig. 9 is a cross-sectional view of a fitted portion of a steering tube assembled by the apparatus of Fig. 8.

Fig. 10 shows a bending mechanism incorporated into the apparatus of Fig. 8.

Fig. 11 is a graph showing a relationship between pressing depth and load.

Fig. 12 shows an assembling apparatus according to a third embodiment.

Fig. 13 is a graph showing a relationship between pressing depth and load.

Fig. 14 shows examples of [fine] wire members.

Fig. 15 shows examples of the cross-section of the [fine] wire members.

Figs. 16(A) and (B) show two examples of the [fine] wire members.

Figs. 17(A), (B), (C), and (D) show another two examples of the [fine] wire members.

Figs. 18(A), (B), (C), (D) and (E) show further examples of the [fine] wire members.

Figs. 19(A), (B), (C), (D), (E), and (F) show further examples of [fine] wire members.

Figs. 20(A), (B), (C), (D), (E), (F), and (G) show further examples of [fine] wire members.

Figs. 21(A), (B), (C), and (D) show the relationship between the [fine] wire members and the end face of the tube.

Figs. 22(A), (B), (C), (D), (E), and (F) show the relationships between different arrangements of the [fine] wire members and axial rigidity.

Figs. 23(A), (B), (C), (D), (E), and (F) show examples of different arrangements of the [fine] wire members.

BEST MODE FOR PRACTICING THE INVENTION

Embodiments according to the present invention will hereinafter be described with reference to the accompanying drawings. Figs. 1 and 2 schematically show the positional relationship of inner tube IN fitted within outer tube OU. The outer shape of inner tube IN has a circular cross section and the inner shape of outer tube OU also has a circular cross-section. The inner diameter of outer tube OU is larger than the outer diameter of inner tube IN. When both tubes are fitted together, annular-shaped gap G is defined between tubes IN and OU. A plurality of wire members (hereinafter referred to as fine members) W is fitted within gap G between tubes IN and OU. The outer diameter of each of fine members W, before being fitted therein, is larger than the width of gap G, which means that fine members W are squeezed within gap G. Fine members W are disposed such that outer tube OU and inner tube IN are maintained at coaxial relationship. The number of fine members is preferably greater than or equal to three. However, two bent fine members also can be utilized to maintain inner tube IN and outer tube OU at coaxial relationship.

Page 16, line 21 to page 17, line 31:

Please amend the paragraph starting at page 16, line 21 and ending on page 17, line 31 (end of page) as follows:

In a steering tube assembled in such a manner, outer tube OU is press-fitted around inner tube IN, four fine members W are disposed a predetermined length along the inner shape of outer tube OU and the four fine members W are prohibited from being axially pulled further into outer tube OU. Accordingly, fine member W extends between inner tube IN and outer tube OU and has been cut at a predetermined length. This feature contributes to ensuring uniform energy absorption performance. Four fine members W extending along a straight line along an axis separate inner tube IN and outer tube OU from each other (i.e., clearance G exists in the space in which there is no fine member W), thereby preventing inner tube IN from directly contacting outer tube OU. This feature also contributes to ensuring uniform energy absorption performance. After assembling the steering tube, fine member W remains bent and fixed to the upper end face of outer tube OU. If energy is applied to both tubes IN and OU so that inner tube IN is pressed more deeply into outer tube OU, fine members W will reliably guide inner tube IN during the pressing operation while remaining fixedly coupled to the upper end face of outer tube OU. In addition, because fine members W are fixedly coupled to the upper end face of outer tube OU and are prohibited from moving in the axial direction, the energy absorption performance is uniform when energy is being absorbed. Further, by using a sufficient length of fine member W, tubes IN and OU are maintained in a parallel relationship when inner tube IN is pressed deeply into the outer tube OU. This sufficient length also prevents both tubes from bending and thus contacting each other. This feature prevents inner tube IN from directly contacting outer tube OU when energy is absorbed. The axial length of fine member W is predetermined in order to prevent inner tube IN from directly contacting outer tube OU when inner tube IN is further pressed into outer tube OU in order to absorb energy. Accordingly, the energy absorption performance is uniform when energy is absorbed. If three or more fine members are used, the tubes can be maintained in a parallel relationship. Therefore, any number of fine members, not less than three, may be used. In addition, two bent fine members can be utilized to fit together both tubes while providing a clearance between the tubes.